

WHAT IS CLAIMED IS:

1. A phosphor comprising a material having a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)(P_{1-q}B_q)O_4$; wherein $0 < x, y, z < 1$; $0 < x+y+z < 1$; and $0 < q < 1$.
2. The phosphor according to claim 1, wherein $0.2 \leq q < 1$.
3. The phosphor according to claim 1, wherein $0 < q \leq 0.2$.
4. The phosphor according to claim 1, wherein q is in a range from about 0.2 to about 1, x is in a range from about 0.005 to about 0.3; y is in a range from about 0.005 to about 0.2; and z is in a range from about 0.3 to about 0.9.
5. The phosphor according to claim 1, wherein q is in a range from about 0.2 to about 1, x is in a range from about 0.005 to about 0.2; y is in a range from about 0.005 to about 0.1; and z is in a range from about 0.4 to about 0.7.
6. A phosphor comprising a material having a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)(P_{1-q}B_q)O_4$; wherein $0 < x, y < 1$; $0 < x+y+z < 1$; $0 \leq q < 1$; and $0.3 < z < 1$.
7. A phosphor comprising a material having a formula of $(La_{1-x-y-z-u-v}Tb_xCe_yGd_zD_uE_v)(P_{1-q}B_q)O_4$; wherein D is at least an element selected from the group consisting of Pr, Nd, Sm, Eu, Dy, Ho, Er, Tm, and Yb; E is at least an element selected from the group consisting of Sc, Y, and Lu; $0 \leq q < 1$; x is in a range from about 0.005 to about 0.3; y is in a range from about 0.005 to about 0.2; z is in a range from about 0.3 to about 0.9; u is in a range from about 10^{-9} to about 0.1; v is in a range from about 10^{-9} to about 0.2; and $0 < x+y+z+u+v < 1$.
8. The phosphor according to claim 7, wherein q is in a range from about 0.2 to about 1.
9. The phosphor according to claim 7, wherein D is at least an element selected from the group consisting of Pr, Dy, Nd, and Er; and q is in a range from about 0.2 to about 1.

10. The phosphor according to claim 7, wherein E is Y.
11. A phosphor comprising a material having a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)PO_4$; wherein $0 < x, y < 1$; $0 < x+y+z < 1$; and $0.3 < z < 1$.
12. The phosphor according to claim 11, wherein x is in a range from about 0.01 to about 0.2; y is in a range from about 0.005 to about 0.1; and z is in a range from about 0.4 to about 0.7.
13. A phosphor comprising a material having a formula of $(La_{1-x-y-z-t}Tb_xCe_yGd_zJ_t)(P_{1-q}B_q)O_4$; wherein J is at least an element selected from the group consisting of Ti, Zr, and Hf; $0 \leq q < 1$; x is from about 0.005 to about 0.3; z is in a range from about 0.3 to about 0.9; y is in a range from about 0.005 to about 0.2; t is in a range from about 10^{-9} to about 0.05; and $0 < x+y+z+t < 1$.
14. The phosphor according to claim 13, wherein J is Zr, and t is in a range from about 0.0001 to about 0.02.
15. A phosphor comprising a material having a formula of $(La_{0.1}Tb_{0.15}Ce_{0.05}Gd_{0.7})PO_4$.
16. A phosphor comprising a material having a formula of $(La_{0.2}Tb_{0.15}Ce_{0.05}Gd_{0.6})PO_4$.
17. A phosphor comprising a material having a formula of $(La_{0.25}Tb_{0.15}Ce_{0.1}Gd_{0.5})PO_4$.
18. A phosphor blend comprising: (a) a phosphor having a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)(P_{1-q}B_q)O_4$; wherein $0 < x, y, z < 1$; $0 < x+y+z < 1$; and $0 \leq q < 1$; (b) a red light-emitting phosphor; and (c) a blue light-emitting phosphor.
19. The phosphor blend according to claim 18, wherein $q = 0$.
20. The phosphor blend according to claim 18, wherein $q = 0$, and $0.3 < z < 1$.

21. The phosphor blend according to claim 18, wherein $q = 0$, $x = 0.15$, $y = 0.05$, and $z = 0.7$.
22. The phosphor blend according to claim 18, wherein $q = 0$, $x = 0.2$, $y = 0.05$, and $z = 0.6$.
23. The phosphor blend according to claim 18, wherein $q = 0$, $x = 0.25$, $y = 0.1$, and $z = 0.5$.
24. A phosphor blend comprising: (a) a phosphor having a formula of $(La_{1-x-y-z-u-v}Tb_xCe_yGd_zD_uE_v)(P_{1-q}B_q)O_4$; wherein D is at least an element selected from the group consisting of Pr, Nd, Sm, Eu, Dy, Ho, Er, Tm, and Yb; E is at least an element selected from the group consisting of Sc, Y, and Lu; $0 \leq q < 1$; x is in a range from about 0.005 to about 0.3; y is in a range from about 0.005 to about 0.2; z is in a range from about 0.3 to about 0.9; u is in a range from about 10^{-9} to about 0.1; v is in a range from about 10^{-9} to about 0.2; and $0 < x+y+z+u+v < 1$; (b) a red light-emitting phosphor; and (c) a blue light-emitting phosphor.
25. A phosphor blend comprising: (a) a phosphor having a formula of $(La_{1-x-y-z-t}Tb_xCe_yGd_zJ_t)(P_{1-q}B_q)O_4$; wherein J is at least an element selected from the group consisting of Ti, Zr, and Hf; $0 \leq q < 1$; x is from about 0.005 to about 0.3; z is in a range from about 0.3 to about 0.9; y is in a range from about 0.005 to about 0.2; t is in a range from about 10^{-9} to about 0.05; and $0 < x+y+z+t < 1$; (b) a red light-emitting phosphor; and (c) a blue light-emitting phosphor.
26. A method for making a phosphor, the method comprising:
- (a) mixing oxygen-containing compounds of: (1) at least an element selected from the group consisting of phosphorus and boron; (2) at least an element selected from the group consisting of elements of Group IIIA, elements of Group IVA, and elements of lanthanide series other than cerium and terbium; (3) cerium, and (4) terbium to form a mixture; and

- (b) firing the mixture in a reducing atmosphere at a temperature in a range from about 900 C to about 1300 C for a time sufficient to convert the mixture to the phosphor.

27. The method according to claim 26; wherein said elements of Group IIIA and said elements of lanthanide series comprise La and Gd; amounts of said oxygen-containing compounds are chosen such that said phosphor has a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)(P_{1-q}B_q)O_4$; wherein $0 < x, y, z < 1$; $0 < x+y+z < 1$; and $0 < q < 1$.

28. The method according to claim 27, wherein $0.2 < q < 1$.

29. The method according to claim 26, wherein the mixture further comprises at least a material selected from the group consisting of lithium tetraborate, lithium carbonate, alkali hydrogen phosphate, and alkali phosphate.

30. A method for making a phosphor, the method comprising:

- (a) providing a first solution that comprises compounds of: (1) at least a first element selected from the group consisting of phosphorus and boron; (2) at least a second element selected from the group consisting of elements of Group IIIA, elements of Group IVA, and elements of lanthanide series other than cerium and terbium; (3) cerium, and (4) terbium;
- (b) combining the first solution and a second solution, the second solution comprising at least a compound selected from the group consisting of ammonium hydroxide; hydroxides of at least one element selected from the group consisting of cerium, terbium, said elements of Group IIIA, elements of Group IVA, and lanthanide series; organic esters; organic dicarboxylic acids; phosphoric acid; and organic amines to produce a precipitate;
- (c) heating the precipitate in an oxygen-containing atmosphere at a temperature in a range from about 700 C to about 1300 C for a time

sufficient to convert the precipitate to an oxygen-containing material that comprises said at least a first element, said at least a second element, cerium, and terbium; and

(d) firing said oxygen-containing material in a reducing atmosphere at a temperature in a range from about 900 C to about 1300 C for a time sufficient to convert said oxygen-containing material to the phosphor.

31. The method according to claim 30; wherein said elements of Group IIIA and said elements of lanthanide series comprise La and Gd; amounts of said oxygen-containing compounds are chosen such that said phosphor has a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)(P_{1-q}B_q)O_4$; wherein $0 < x, y, z < 1$; $0 < x+y+z < 1$; and $0 \leq q < 1$.

32. The method according to claim 31, wherein $0.2 < q < 1$.

33. A method for making a phosphor, said method comprising:

(a) providing a first solution that comprises compounds of: (1) at least an element selected from the group consisting of elements of Group IIIA, elements of Group IVA, and elements of lanthanide series other than cerium and terbium; (2) cerium, and (3) terbium;

(b) combining the first solution and a second solution, the second solution comprising at least a compound selected from the group consisting of ammonium hydroxide; hydroxides of at least one element selected from the group consisting of cerium, terbium, said elements of Group IIIA, Group IVA, and lanthanide series; organic esters; organic dicarboxylic acids; phosphoric acid; and organic amines to produce a precipitate;

(c) heating the precipitate in an oxygen-containing atmosphere at a temperature in a range from about 700 C to about 1300 C for a time sufficient to convert the precipitate to an oxygen-containing material that comprises said at least an element selected from the group

consisting of said elements of Group IIIA, said elements of Group IVA, and said elements of lanthanide series, cerium, and terbium;

(d) combining said oxygen-containing material with at least an oxygen-containing compound of at least one of phosphorus and boron; and

(e) firing said oxygen-containing material in a reducing atmosphere at a temperature in a range from about 900 C to about 1300 C for a time sufficient to convert said oxygen-containing material to the phosphor.

34. The method according to claim 33; wherein said elements of Group IIIA, and said elements of lanthanide series comprise La and Gd; amounts of said oxygen-containing compounds are chosen such that said phosphor has a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)(P_{1-q}B_q)O_4$; wherein $0 < x, y, z < 1$; $0 < x+y+z < 1$; and $0 \leq q < 1$.

35. The method according to claim 34, wherein $0.2 < q < 1$.

36. A light source comprising:

(a) a source of UV radiation that is located in a sealed housing; and

(b) a phosphor disposed within the sealed housing and adapted to be excited by the UV radiation and to emit visible light, wherein the phosphor comprises a material having a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)(P_{1-q}B_q)O_4$; wherein $0 < x, y, z < 1$; $0 < x+y+z < 1$; and $0 \leq q < 1$.

37. The light source according to claim 36, wherein $0.2 < q < 1$.

38. The light source according to claim 36, wherein $0 < x, y < 1$; $0 < x+y+z < 1$; $0 \leq q < 1$; and $0.3 < z < 1$.

39. The light source according to claim 36, wherein the source of UV radiation is a mercury gas discharge.

40. A light source comprising:

- (a) a source of UV radiation that is located in a sealed housing; and
- (b) a phosphor disposed within the sealed housing and adapted to be excited by the UV radiation and to emit visible light, wherein the phosphor comprises a material having a formula of $(La_{1-x-y-z-u-v}Tb_xCe_yGd_zD_uE_v)(P_{1-q}B_q)O_4$; wherein D is at least an element selected from the group consisting of Pr, Nd, Sm, Eu, Dy, Ho, Er, Tm, and Yb; E is at least an element selected from the group consisting of Sc, Y, and Lu; $0 \leq q < 1$; x is in a range from about 0.005 to about 0.3; y is in a range from about 0.005 to about 0.2; z is in a range from about 0.3 to about 0.9; u is in a range from about 10^{-9} to about 0.1; v is in a range from about 10^{-9} to about 0.2; and $0 < x+y+z+u+v < 1$.

41. A light source comprising:

- (a) a source of UV radiation that is located in a sealed housing; and
- (b) a phosphor blend disposed within the sealed housing and adapted to be excited by the UV radiation and to emit visible light, wherein the phosphor blend comprises: (1) a phosphor comprising a material having a formula of $(La_{1-x-y-z}Tb_xCe_yGd_z)(P_{1-q}B_q)O_4$; wherein $0 < x, y, z < 1$; $0 < x+y+z < 1$; $0 \leq q < 1$; x is in a range from about 0.005 to about 0.3; y is in a range from about 0.005 to about 0.2; and z is in a range from about 0.3 to about 0.9; (2) at least a red light-emitting phosphor; and (3) at least a blue light-emitting phosphor.

42. A light source comprising:

- (a) a source of UV radiation that is located in a sealed housing; and
- (b) a phosphor blend disposed within the sealed housing and adapted to be excited by the UV radiation and to emit visible light, wherein the phosphor blend comprises: (1) a material having a formula of $(La_{1-x-y-z}$

$_{u}\text{Tb}_x\text{Ce}_y\text{Gd}_z\text{D}_u\text{E}_v)(\text{P}_{1-q}\text{B}_q)\text{O}_4$; wherein D is at least an element selected from the group consisting of Pr, Nd, Sm, Eu, Dy, Ho, Er, Tm, and Yb; E is at least an element selected from the group consisting of Sc, Y, and Lu; $0 \leq q < 1$; x is in a range from about 0.005 to about 0.3; y is in a range from about 0.005 to about 0.3; z is in a range from about 0.3 to about 0.9; u is in a range from about 10^{-9} to about 0.1; and v is in a range from about 10^{-9} to about 0.2; (2) at least a red light-emitting phosphor; and (3) at least a blue light-emitting phosphor.

43. A light source comprising:

- (a) a source of UV radiation that is located in a sealed housing; and
- (b) a phosphor blend disposed within the sealed housing and adapted to be excited by the UV radiation and to emit visible light, wherein the phosphor blend comprises: (1) a material having a formula of $(\text{La}_{1-x-y-z-t}\text{Tb}_x\text{Ce}_y\text{Gd}_z\text{J}_t)(\text{P}_{1-q}\text{B}_q)\text{O}_4$; wherein J is at least an element selected from the group consisting of Ti, Zr, and Hf; $0 \leq q < 1$; x is in a range from about 0.005 to about 0.3; y is in a range from about 0.005 to about 0.3; z is in a range from about 0.3 to about 0.9; u is in a range from about 10^{-9} to about 0.1; t is in a range from about 10^{-9} to about 0.05; and $0 < x+y+z+t < 1$; (2) at least a red light-emitting phosphor; and (3) at least a blue light-emitting phosphor.